1 INTRODUCTION

1.1 Background

In October 1999, the two divisions of the Advanced Photon Source (APS), the Accelerator Systems Division (ASD) and the Experimental Facilities Division (XFD), were reorganized into four divisions (see high-level APS organizational chart, Fig. 1.1). In addition to ASD and XFD, two new divisions were created, the APS Operations Division (AOD), to oversee APS operations, and the User Program Division (UPD), to serve the APS user community by developing and maintaining the highest quality user technical and administration support. Previous XFD *Progress Reports* (ANL/APS/TB-30 and ANL/APS/TB-34) covered a much broader base, including APS user administrative support and what was previously XFD operations (front ends, interlocks, etc.) This *Progress Report* summarizes the main scientific and technical activities of XFD, and the technical support, research and development (R&D) activities of UPD from October 1998 through November 2000.

The report is divided into four major sections, 1) Introduction, 2) SRI-CAT Beamlines, Technical Developments, and Scientific Applications, 3) User Technical Support, and 4) Major Plans for the Future. Sections 2 and 3 describe the technical activities and research accomplishments of the XFD and UPD personnel in supporting the synchrotron radiation instrumentation (SRI) collaborative access team (CAT) and the general APS user community. Also included in this report is a comprehensive list of publications (Appendix 1) and presentations (Appendix 2) by XFD and UPD staff during the time period covered by this report.

The organization of section 2, SRI CAT Beamlines, Technical Developments, and Scientific Applications has been made along scientific techniques/disciplines and not “geographical” boundaries of the sectors in which the work was performed. Therefore items under the subsection X-ray Imaging and Microfocusing could have been (and were) performed on several different beamlines by staff in different divisions. The management of SRI CAT encourages this type of cross-fertilization among the staff responsible for different beamlines and feels that this approach will ultimately result in the best scientific output.

The section on User Technical Support, on the other hand, is laid out more closely along group lines, namely insertion devices, high-heat-load optics, instrumentation engineering, optics fabrication and metrology, and beamline controls and data acquisition.

1.2 Mission of the Experimental Facilities Division

The mission of XFD is to develop and build state-of-the-art synchrotron radiation instrumentation and use it in a safe and environmentally sound manner to conduct world-class research at the forefront of

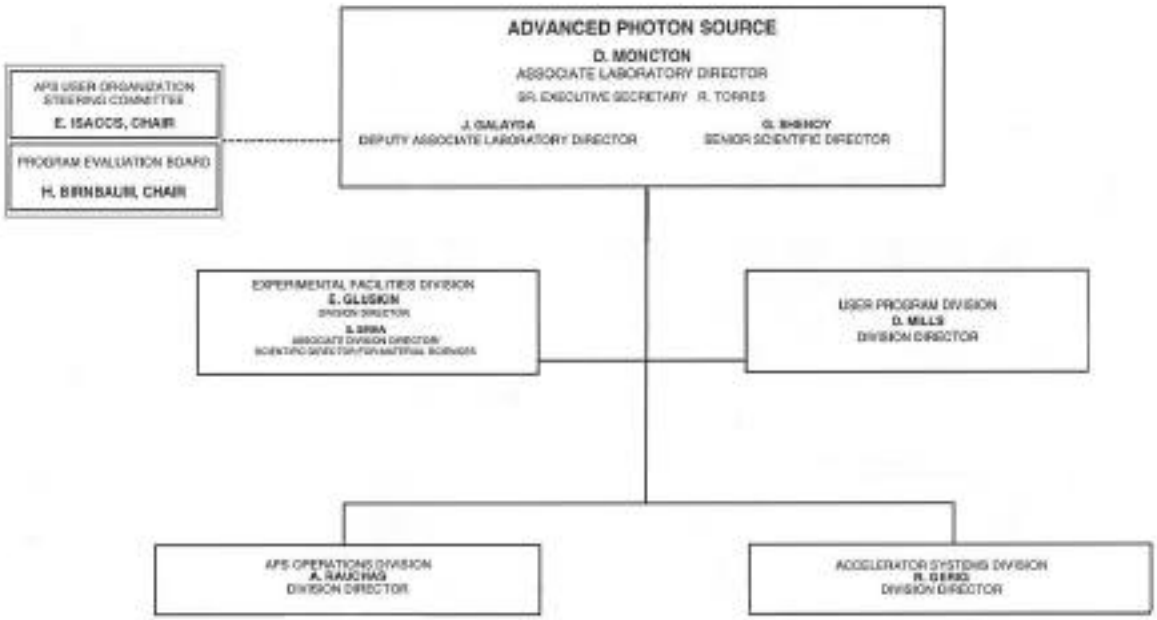

Fig. 1.1. High-level APS organizational chart showing the four divisions.

science and technology. This will enable the success of the APS as a preeminent synchrotron radiation user facility.

Specifically, the mission of XFD is to:

- Develop novel ways of using synchrotron radiation to explore the frontiers of x-ray physics and new scientific applications.
- Develop and build novel radiation sources for the APS and for the next generation of synchrotron radiation sources.
- Develop and build innovative instrumentation for front ends, beam-lines, and experiment stations, for the APS and for the next generation of synchrotron radiation sources.
- Provide continuous technical support to APS users by sharing the technical capabilities, as well as the scientific and technical developments of the division.

1.3 Mission of the User Program Division

The mission of UPD is to serve the APS user community by developing and maintaining the highest quality user technical and administration support and through innovative R&D in support of the scientific programs at the APS.

This mission can be best achieved through the following principles:

- Developing a thorough understanding of the users' needs and goals and striving to exceed them.
- Creating an enriching, fulfilling, and collaborative R&D environment for the UPD staff and APS users to facilitate the development of new synchrotron radiation instrumentation and techniques that will enhance and ensure the long-term success of the APS.
- Engendering new areas of scientific research at the APS and educating and nurturing new research communities in the uses and applications of synchrotron radiation.
- Assuring the safety and well-being of APS users, APS/UPD personnel, visitors, and the environment.

1.4 XFD and UPD Organization

The XFD and UPD organization has two functional areas as shown in Fig 1.2. This *Progress Report* (and the review) will cover the technical support and R&D areas. These include the XFD and UPD organization structures, shown in Fig 1.3, which define various groups by specialization. This structure enables excellent communication and interaction across the boundaries of the groups to meet both the groups' and APS's objectives. Although most activities within a division are line managed, SRI CAT, which pulls its membership from both divisions (as well as from outside Argonne National Laboratory), is managed in a matrix fashion.

Although neither of these divisions has direct responsibility for the day-to-day operation of the facility, needless to say there is close communications between XFD/UPD and ASD/AOD. SRI CAT staff provide first-hand information to APS management through the XFD and UPD division directors on the performance of the storage ring. This information is used as diagnostics by the operations staff for further enhancement of the storage ring performance.

1.5 SRI CAT and R&D in Support of Users

The SRI CAT divides its membership into two categories, Developers and Scientific Members. Developers are financial contributors to the SRI CAT and consist of members from XFD and UPD, staff from several U.S. universities and national laboratories (X-ray Physics Group), and members of the Australian Synchrotron Radiation Project (ASRP). Scientific Members are non-paying members that are proposed by the Developers as close scientific collaborators. (A list of Developers and Scientific Members of the SRI CAT during this time period can be found in Appendix 3.) Through Scientific Members, SRI CAT has been able to reach out to a larger community to draw on their scientific expertise to further enhance the scientific output of the CAT.

SRI CAT Developers have made a major impact on the development of new synchrotron radiation optics, instrumentation, and techniques and continue to provide R&D support, advice, and guidance to the other APS CATs in these areas. And over the past two years, Scientific Members of SRI CAT have participated extensively with the XFD and UPD staff in performing

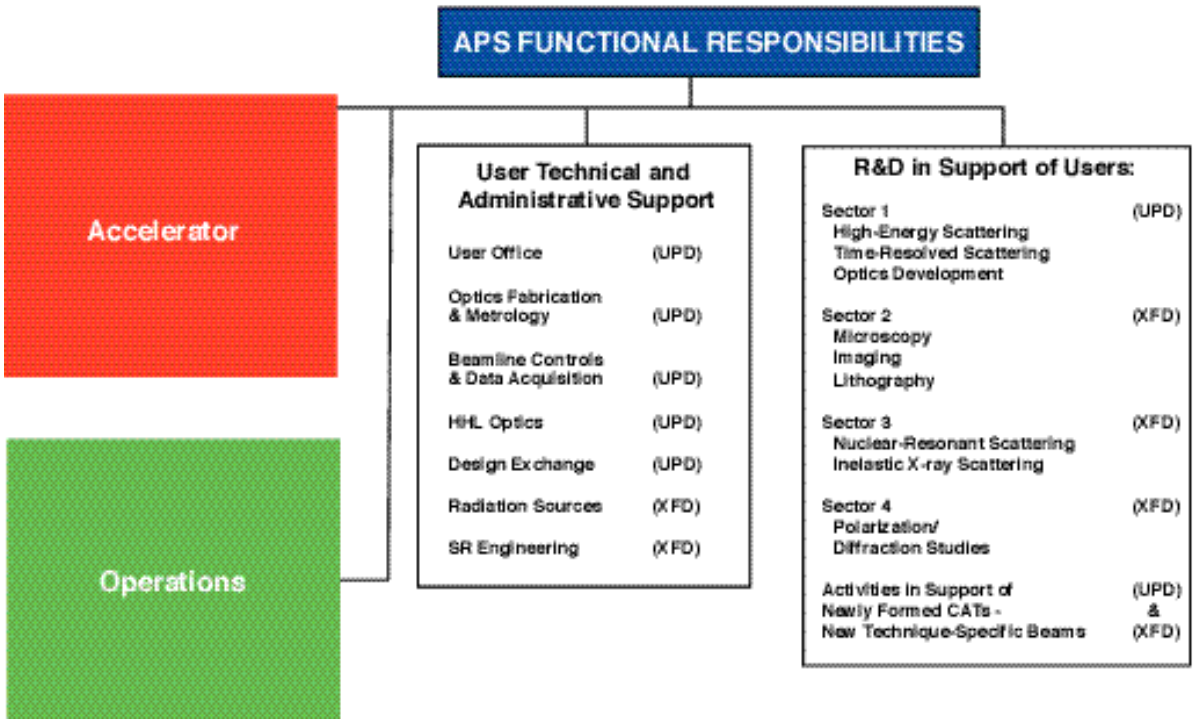

Fig. 1.2. APS functional responsibilities. This report will cover: user technical support and R&D in support of user operations and science.

frontier scientific research utilizing these new instruments and techniques. More details of the accomplishments of SRI CATcan be found in the next section of this report.

Besides instrumentation development, SRI CAT has served the synchrotron radiation community in other ways as well. Although SRI CAT is not directly involved in APS operations, it has made considerable contributions in this area too. SRI CAT often serves as a test-bed for new accelerator concepts, such as the canted undulator scheme for producing two beamlines from a single straight section which we have implemented in sector 4. The SRI CAT played an important part in better understanding the effect of top-up on photon beam stability and how these effects can be mitigated through gating techniques. And recently the storage ring was reconfigured in sectors 2, 3, and 4 to implement the so-called Decker distortion for improved insertion device beam position monitor reliability that should eventually lead to improved beam stability through the development of local feedback schemes.

The SRI CAT was the first CAT to accept independent investigator proposals for beam time, and, during the time covered by this report, we have hosted approximately 120

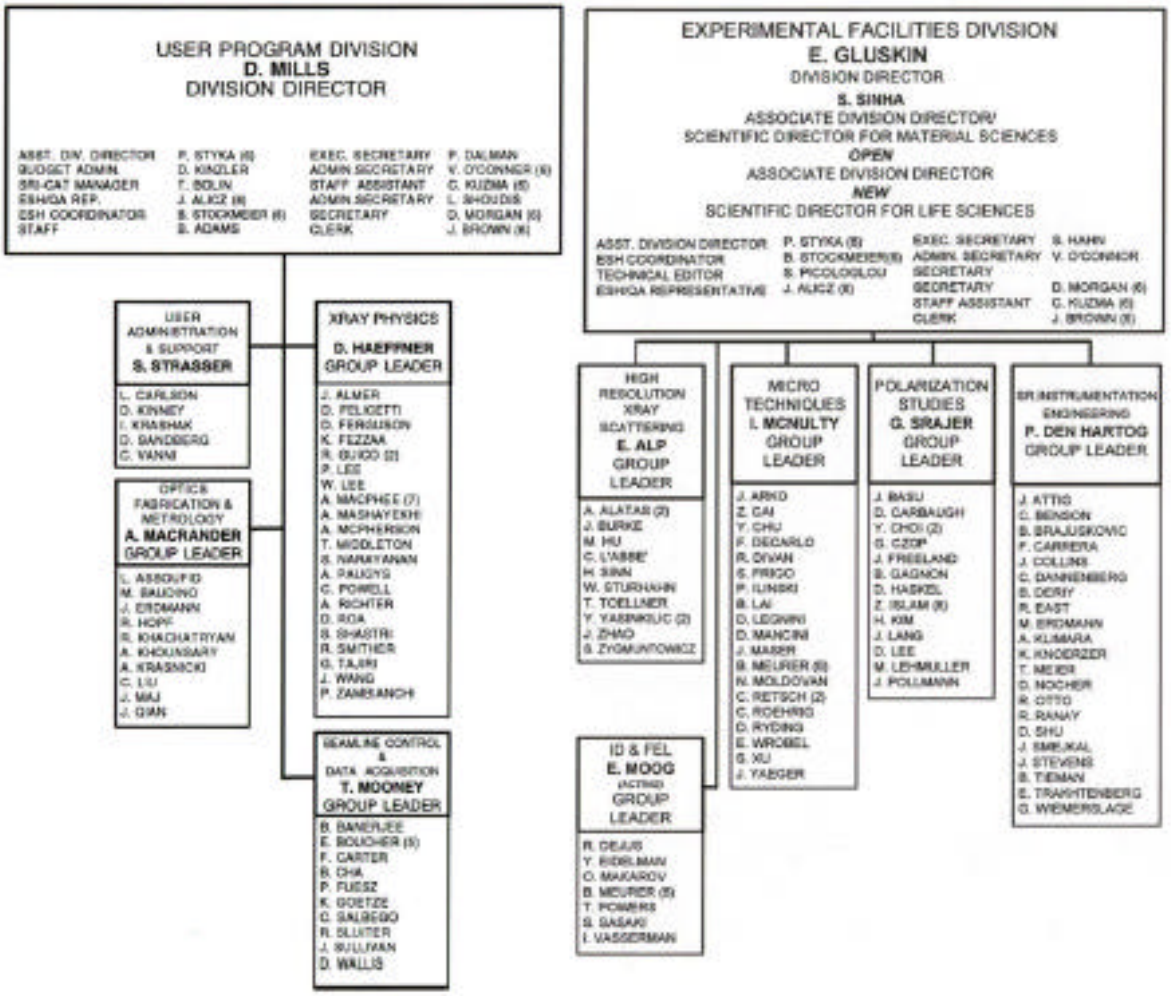

Fig. 1.3. UPD and XFD Organizational Charts.

independent investigators on our beamlines. Members of SRI CAT have also played important roles (Scientific Co-Director and Laboratory Coordinator) in the development and running of the National School for Neutron and X-ray Scattering, which has been hosted by Argonne National Laboratory (ANL) the last two summers. The goal of the school is to provide training for graduate students in the utilization of national user facilities, such as the APS. In addition to the organizational aspects of the school, many of the SRI CAT staff lectured and participated in the laboratory experiments that were performed on APS beamlines.

1.6 APS Free-Electron Laser Developments

In the last several years, the APS has been developing a new type of radiation source based on the self-amplified spontaneous

emission (SASE) process. The synchrotron radiation community recognizes that this type of source ultimately will be the next-generation synchrotron radiation source. Previous XFD *Progress Reports* contained information on the status of these developments.

In close collaboration with ASD, XFD continues to play a major part in the APS efforts to develop, characterize and use a novel SASE free-electron laser (FEL) source as a basis for the next-generation of synchrotron radiation sources. Recently it was a remarkable technical breakthrough in this area when for the first time the record high amplification has been achieved and experimental observation of the saturation process took place. XFD staff contributed to this success by designing and building the undulator-based amplifier and radiation diagnostics equipment.

Although in the last two years these activities have been a substantial part of XFD effort, they will not be covered in this report. A special comprehensive report on the SASE FEL will be generated by ASD and XFD in the near future.

1.7 User Technical Support

User technical support is distributed between the Experimental Facilities and User Program Divisions. The role of the user technical support groups is not only to provide services to users on a daily basis but also to anticipate future problems that might arise and to initiate the appropriate R&D programs now so that solutions can be found in a timely manner. Anticipation of future problems can only be achieved if the technical groups are in close contact with the research scientists, such as those of SRI CAT. This close integration of the SRI CAT members and technical support staffs has been achieved by distributing staff from both activities into XFD and UPD and not isolating the two activities in two separate divisions.

X-ray optics support, the APS Design Exchange, and support for beamlines controls is located in UPD, while insertion device development and beamline component engineering is performed primarily in XFD.

1.8 Collaborative Work

The XFD and UPD actively collaborate with other divisions within ANL and with other synchrotron radiation facilities. One of the formal ways to develop collaborations within the laboratory is through the use of Laboratory Directed Research and Development (LDRD) funds. One type of LDRD, the Coordination Council for Science and Technology (CCST) encourages collaborations between basic and applied programs, and we have participated in that program through a proposal entitled "Application of Synchrotron Radiation for Diesel Fuel Spray Characterization." Another funded LDRD proposal, "High-Throughput Biomolecular Structure Determination," has members from both XFD and UPD along with staff from the Biological Sciences, Mathematics and Computer Science, and Environmental Research Divisions. Similarly the "X-ray Magnetic Microscopy Development" LDRD was coauthored by SRI CAT staff and

Materials Science Division (MSD) personnel.

The XFD and UPD also received funding through the "4th-Generation Light Source Development" LDRD. This funding permitted collaboration with other national laboratories and international collaborations as well. As a result of collaborations with Stanford Synchrotron Radiation Laboratory (SSRL) on the Linac Coherent Light Source (LCLS) project and with Hamburger Synchrotronstrahlungslabor (HASYLAB) on the TESLA project, novel insertion devices (IDs) and ID vacuum chambers have been developed. In collaboration with the TESLA FEL facility at Deutsches Elektronen-Synchrotron (DESY) a conceptual design and cost estimate for a fourth-generation beamline has been developed. A similar collaboration has recently been undertaken with the LCLS Project.

Non-LDRD funded collaborations include those with Berliner Elektronenspeicherring-Gesellschaft für Synchrotronstrahlung (BESSY) and the Swiss Light Source (SLS) for the development and construction of ID vacuum chambers for these facilities. And several high-heat-load front-end components have been developed for the European Synchrotron Radiation Facility (ESRF) and Super Photon Ring – 8 GeV (SPring-8) in Japan. We also have an ongoing collaboration with the National High Magnetic Field Laboratory to explore the possibility of developing a high magnetic field facility on one of the SRI CAT beamlines.

1.9 Long-Term R&D Plans

The long-term R&D plans for the technical staff of both divisions fall into three categories, continued cutting-edge instrumentation and technique development to pursue state-of-the-art science in sectors 1-4, conceiving and designing "second-generation" beamlines for proposed new CATS at the APS, and preparing the way with both instrumentation and scientific applications for a fourth-generation synchrotron radiation source, namely an x–ray FEL.

Keeping the quality of the instrumentation and technique development on the SRI CAT at a world-class status will remain a high priority within XFD and UPD. We look forward to the commissioning of the soft x–ray circularly polarized undulator (CPU) and to improvements in high-energy-resolution monochromator and analyzer development for inelastic x-ray scattering. Considerable effort will be applied to push the current x-ray microprobes into the realm of nanoprobes. Development of the backscattering beamline on sector 1 will continue for use in fundamental studies of the physics of Bragg scattering at exactly 90° and the applications of such a backscattered beam. These and other new instrument developments will permit the staff to continue to pursue forefront science and become respected scientific innovators and leaders in their fields.

Several of the SRI CAT staff have become involved with newly formed CATS, such as the inelastic x-ray scattering (IXS) CAT, the

high-energy x-ray (HEX) CAT, and the nanoscience (Nano) CAT. The instrumentation and techniques around which all three of these CATs are based has been developed at SRI CAT. But rather than duplicate an existing beamline design for these proposed CATs, we plan to build on the experience gained in construction and operation of SRI CAT beamlines to develop "second-generation" beamlines for these CATs with source and beamline characteristics improved over the existing APS beamlines. These new beamlines will require R&D on specialized insertion devices, improved optical components, and enhanced instrumentation development. Because of the close relationship between these proposed beamlines and the current SRI CAT lines, much of the R&D on the new beamline components can be performed on the existing SRI CAT beamlines while the new beamlines are under construction.

Anticipating that the LCLS construction project will be funded, we are laying the foundations for our involvement in this project and eventually in a fourth-generation light source facility. In that regards, we plan to continue R&D programs that will keep us in the forefront of the science and technology required for these projects. This includes insertion device development, optics for x–ray FELs, ultrafast pump/probe techniques, and the use and applications of fully coherent x-ray beams.

These are a few of the future technical R&D challenges that we see on the horizon. An equal challenge will be how to accomplish this R&D in a way so as to maintain our high level of operational support for scientists using SRI CAT and the overall technical support for the APS user community.